National, regional, and worldwide estimates of stillbirth rates in 2009 with trends since 1995: a systematic analysis

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Summary

Background **Stillbirths do not count in routine worldwide data-collating systems or for the Millennium Development Goals. Two sets of national stillbirth estimates for 2000 produced similar worldwide totals of 3·2 million and 3·3 million, but rates differed substantially for some countries. We aimed to develop more reliable estimates and a time series from 1995 for 193 countries, by increasing input data, using recent data, and applying improved modelling approaches.**

Methods **For international comparison, stillbirth is defined as fetal death in the third trimester (≥1000 g birthweight or ≥28 completed weeks of gestation). Several sources of stillbirth data were identified and assessed against prespecified inclusion criteria: vital registration data; nationally representative surveys; and published studies identified through systematic literature searches, unpublished studies, and national data identified through a WHO country consultation process. For 2009, reported rates were used for 33 countries and model-based estimates for 160 countries. A regression model of log stillbirth rate was developed and used to predict national stillbirth rates from 1995 to 2009. Uncertainty ranges were obtained with a bootstrap approach. The final model included log(neonatal mortality rate) (cubic spline), log(low birthweight rate) (cubic spline), log(gross national income purchasing power parity) (cubic spline), region, type of data source, and definition of stillbirth.**

Findings **Vital registration data from 79 countries, 69 nationally representative surveys from 39 countries, and 113 studies from 42 countries met inclusion criteria. The estimated number of global stillbirths was 2·64 million (uncertainty range 2·14 million to 3·82 million) in 2009 compared with 3·03 million (uncertainty range 2·37 million to 4·19 million) in 1995. Worldwide stillbirth rate has declined by 14·5%, from 22·1 stillbirths per 1000 births in 1995 to 18·9 stillbirths per 1000 births in 2009. In 2009, 76·2% of stillbirths occurred in south Asia and sub-Saharan Africa.**

Interpretation **This study draws attention to the dearth of reliable data in regions where most stillbirths occur. The estimated trend in stillbirth rate reduction is slower than that for maternal mortality and lags behind the increasing progress in reducing deaths in children younger than 5 years. Improved data and improved use of data are crucial to ensure that stillbirths count in global and national policy.**

Funding **The Bill & Melinda Gates Foundation through the Global Alliance to Prevent Prematurity and Stillbirth, Saving Newborn Lives/Save the Children, and the International Stillbirth Alliance. The Department of Reproductive Health and Research, WHO, through the UN Development Programme, UN Population Fund, WHO, and World Bank Special Programme of Research, Development and Research Training in Human Reproduction.**

Lancet 2011; 377: 1319–30

Published Online
April 14, 2011
DOI:10.1016/S0140-6736(10)62310-0

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Introduction

In 2006, two sets of stillbirth rate estimates for 2000 were published—one by WHO[1] and one by the Saving Newborn Lives/Initiative for Maternal Mortality Programme Assessment (IMMPACT).[2] These reports were the first published national estimates of stillbirth rates. Both generated similar worldwide totals—3·3 million[1] and 3·2 million[2] stillbirths in 2000—and, in some cases, similar regional totals. These worldwide estimates are similar to the worldwide total of early neonatal deaths in 2000 (3·0 million) and are higher than the yearly total of deaths from HIV/AIDS in 2004 (1·8 million).[3] Despite the similarities between the two reports, the estimated country-specific rates differed substantially for several countries, with differences of a factor of two to three for some countries (figure 1).

We use the WHO-agreed definition of stillbirth for international comparison (≥1000 g birthweight or ≥28 completed weeks of gestation).[1,4,5] We identified several areas that need attention to develop the previous work and to take into account recent advances and debates on worldwide estimates.[6] We sought to broaden and update the input data, particularly from low-income countries, and to use the neonatal mortality rate rather than the infant mortality rate as a model predictor, because the neonatal mortality rate is more closely associated with factors affecting stillbirth (eg, care during pregnancy and around the time of birth). Both the WHO[1] and Saving Newborn Lives/IMMPACT[2] stillbirth estimates had difficulties with generation of plausible estimates for high-mortality countries, partly because of the scarce availability of data of reasonable quality from

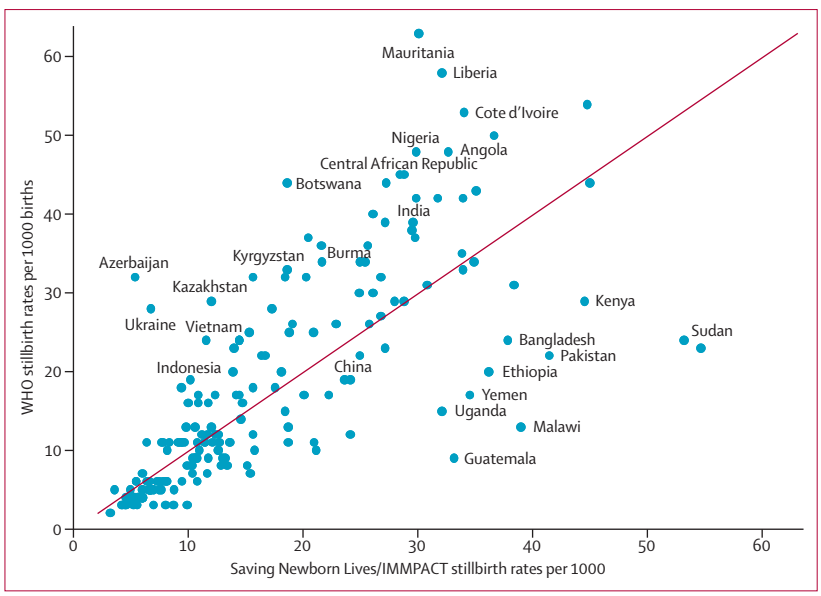

Figure 1: **Data from WHO[1] and Saving Newborn Lives/IMMPACT[2] estimates**
The red line is a 45° line indicating equality between the two sets of estimates. IMMPACT=Initiative for Maternal Mortality Programme Assessment.

For more on the **ORC Macro** see http://www.statcompiler.com

sub-Saharan Africa and Asia. In response to this difficulty, both groups made post-modelling adjustments to their estimates for several countries. We estimate that these adjustments resulted in increases in the estimated number of worldwide stillbirths of 565 000 (WHO)[1] and 670 000 (Saving Newborn Lives/IMMPACT),[2] which is equivalent to increases of 17% and 21%, respectively, in the worldwide number of stillbirths. In this new exercise undertaken jointly with WHO, we aimed to avoid such adjustments to the estimates.

In this Article, we estimate national, regional, and worldwide stillbirth rates and numbers for 193 countries in 2009, retrospectively estimating to 1995 using the same model, and we provide a quantitative assessment of the uncertainty of these estimates. We also present detailed individual-country rates for 2008 for ease of comparison with existing data on neonatal and maternal mortality rates.

Methods

Data inputs

The input dataset was compiled from three sources. First, data from countries with vital registration systems that report stillbirths, or with specific perinatal mortality reporting systems, were identified; if the data were available, these were accessed and assessed for inclusion. We accessed data from national stillbirth registries, including Euro-Peristat and national statistical websites.[7–12] Additionally, the International Stillbirth Alliance requested data based on the international comparison definition for the most recent year from national stillbirth surveillance experts on their member list.

Second, data from demographic and health surveys (DHS) and reproductive health surveys were compiled directly from the ORC Macro website, and by use of data from the contraceptive calendar in the women's questionnaire. The contraceptive calendar documents women's monthly pregnancy and contraceptive use status for the 60 months before the interview.[13] For the surveys that did not provide stillbirth rate but had contraceptive calendar data, we undertook a special analysis to estimate stillbirth rate, defining the rate as the number of pregnancy losses during or after the seventh month of pregnancy for the 5 years preceding the interview, divided by the sum of livebirths and late pregnancy losses in the same period.

Third, the Saving Newborn Lives/IMMPACT study undertook systematic searches up to June, 2003.[2] We repeated these searches from June, 2003, to September, 2010, using the same key terms in all languages and in several databases, including PubMed, Popline, Latin American and Caribbean Health Science (LILACS), Embase, Web of Science, Cumulative Index to Nursing and Allied Health (CINAHL), and WHO regional databases (Eastern Mediterranean Regional Office [EMRO] Index Medicus, African Index Medicus, Pan American Health Organization [PAHO] Latin America and Caribbean Virtual Health Library, South East Asian Region [SEARO] Index Medicus, and Western Pacific Region [WPRO] Index Medicus). Search terms used included multiple variants of stillbirth and perinatal mortality and Medical Subject Headings terms when available. Data from sources meeting the inclusion criteria were combined with those from the earlier Saving Newborn Lives/IMMPACT exercise[2] after checking for and removing any datapoints before 1995 and any duplicate records.

As the final step in the data-gathering process, the data sources together with the preliminary estimates were circulated to member states of WHO as part of the country consultation. Countries were asked to review the preliminary estimates and datapoints, and provide any relevant additional data, including unpublished data sources. All national statistical databases linked to the UN were searched for stillbirth data. This step led to three times as much vital registration data to be assessed because these data have not been routinely collected before by WHO.

Inclusion and exclusion criteria and duplicates

Reported data were used as the national estimate for 2009 if the national vital registration or surveillance system had a high capture of stillbirths (defined as countries with vital registration data of acceptable quality for maternal mortality ratio reporting),[14] if data for the stillbirth rate were available (international comparison definition of ≥1000 g birthweight or ≥28 completed weeks of gestation), and if data were available for stillbirth rate for any year from 2007 to 2009.

We assessed studies for whether the reported data included more than ten stillbirths and whether a stillbirth rate was given or could be calculated. We applied inclusion criteria, consistent with the previous criteria for Saving Newborn Lives/IMMPACT.[2] Although we aimed to estimate stillbirth rate with the international

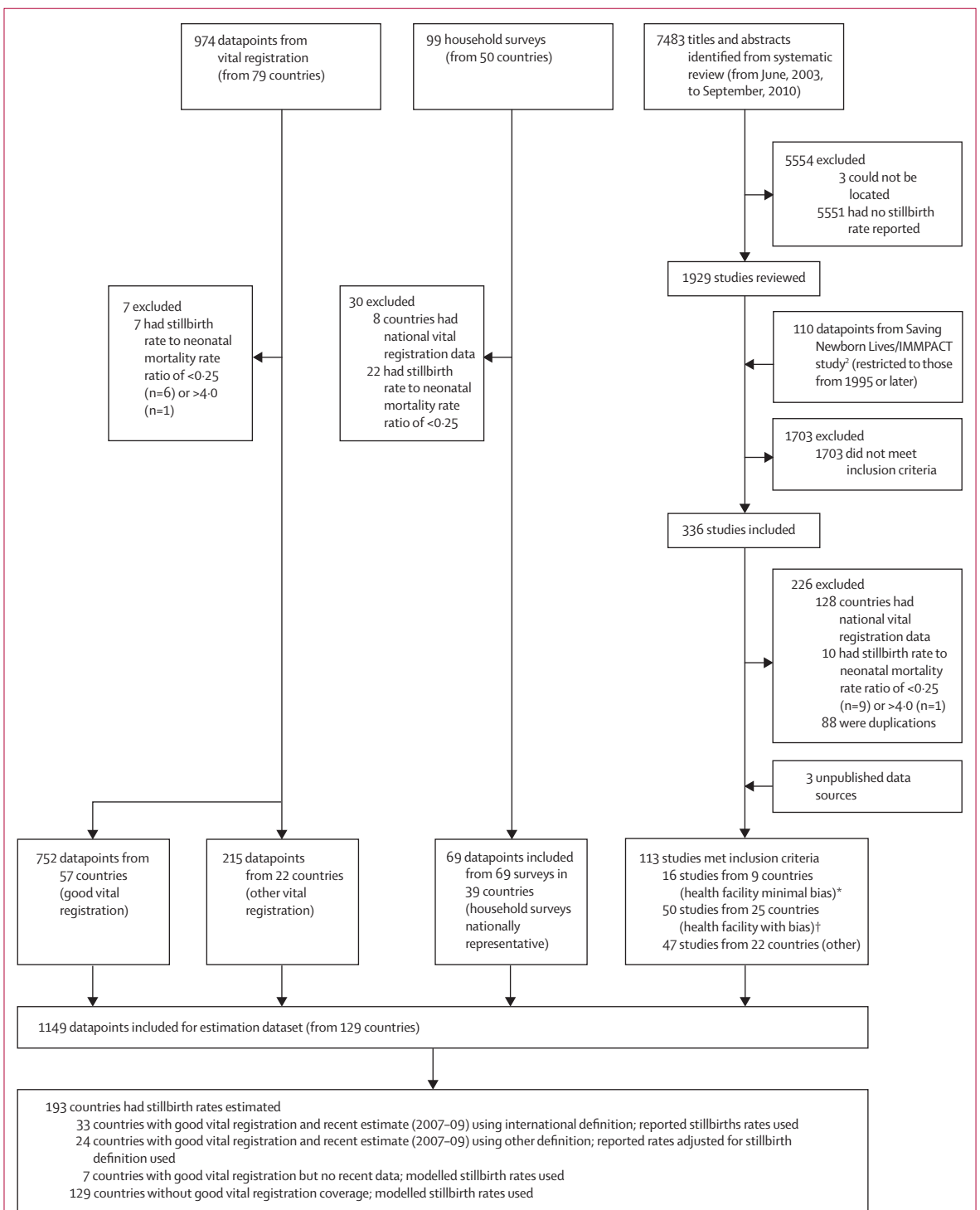

Figure 2: **Search strategy and selection process**
Studied period was 1995–2010. Some countries have more than one datapoint. *Health facility minimal bias: data from sites with more than 90% institutional births. †Health facility data with probable bias: data from sites with low institutional birth rates.

	Median reference year	Data source				Other source	Total number of datapoints
		Vital registration or national stillbirth registry	Nationally representative survey	Health facility (minimal bias)	Health facility (with bias)		
Developed countries	2002	525	0	2	0	0	527
Commonwealth of Independent States	2001	170	7	0	0	0	177
East Asia	1999	3	0	1	1	2	7
Latin America and the Caribbean	2002	135	11	5	4	0	155
North Africa	2000	0	4	0	0	2	6
Oceania	1996	0	0	0	1	0	1
South Asia	2003	11	9	0	20	19	59
Southeast Asia	2001	30	6	3	2	2	43
Sub-Saharan Africa	2002	29	26	3	18	20	96
West Asia	2002	64	6	2	4	2	78
Total (all countries)	2001	967	69	16	50	47	1149

Table 1: **Summary of stillbirth rate data inputs meeting inclusion criteria, by Millennium Development Goal region**

For a **list of countries by region** see http://mdgs.un.org/unsd/mdg/Host.aspx?Content=Data/RegionalGroupings.htm

stillbirth definition of fetal death, we also included data using other definitions (eg, ≥500 g birthweight) and sought to account for the difference in definitions in the modelling. We included only data that had a midpoint of data collection of 1995 or later. We included both population-based and facility-based data, but excluded facility data from specialised service reports (eg, for diabetes, hypertension, intrauterine growth restriction, or specific subpopulations or ethnic groups). We excluded duplicate publications of the same data. As in the report by Saving Newborn Lives/IMMPACT, we included data from health facilities with potential for selection bias and took account of this bias in the modelling process.

For all three data types we plotted the stillbirth rate against neonatal mortality rate for input data, and excluded outlying datapoints with a ratio of stillbirth rate to neonatal mortality rate of less than 0·25 or greater than 4·0. The neonatal mortality rate used was from the dataset in which these data were available; if unavailable, the data were derived from the WHO neonatal mortality rate time series[15] for the relevant country and year for the input data. The final included input dataset is shown in webappendix pp 1–43.

See Online for webappendix

Predictor variables for model input

Covariate data belonging to the following categories were compiled for each stillbirth rate record in the input dataset: (1) stillbirth input data and study characteristics (stillbirth definition used, type of data source, reference year of the stillbirth rate estimate, and source population [urban *vs* rural *vs* mixed]); (2) perinatal outcome indicators (neonatal mortality rate[15] and low birthweight rate[16]); (3) health-service-related indicators (percentage of antenatal care coverage and skilled attendance at birth);[17] and (4) socioeconomic and development indicators (Millennium Development Goal [MDG] region, gross national income purchasing parity power [GNI PPP] per person based on purchasing parity power in current international dollars, total fertility rate, and female literacy rate).[17] We compared the results obtained when using the neonatal mortality rate estimates by WHO and estimates produced by the Institute for Health Metrics and Evaluation.[18]

For subnational datapoints, we used study-level covariates when available, then subnational covariates and, finally national-level covariates. When data were unavailable for the year of study, the figure from the closest year was used. Many additional variables that were specific to the study populations were abstracted during the literature review, but were only available for a few datapoints in the dataset, and, therefore, are not suitable for modelling. Data for early neonatal mortality, syphilis, malaria, consanguinity, and caesarean section were not available for the reference years needed for use with the estimation dataset or for 2009 (for prediction purposes) for all countries. All variables, other than those indicative of study characteristics, were identified for the country and year of the study.

Model fitting

All statistical analyses were done with Stata (version 11). We developed a predictive statistical model for stillbirth rates. We modelled the natural logarithm of the stillbirth rate as the outcome variable. All models were fitted with restricted maximum likelihood estimation and included a country-level random effect. We modelled the association between the outcome and potential continuous predictors by use of restricted cubic splines with three knots located at the 10th, 50th, and 90th centiles of the covariate distribution for countries outside the MDG developed region to ensure a reasonable spread of the knots across the different covariates. Continuous covariates investigated as potential predictors were logs of neonatal mortality rate, GNI PPP, low birthweight rate, skilled birth attendance

rate, antenatal care coverage rate, total fertility rate, and female literacy rate. Inspection of a scatterplot of stillbirth rate versus low birthweight rate indicated that there was no clear association between stillbirth rate and low birthweight rate in countries in the MDG developed countries region in which caesarean section rates are high. Therefore, we chose to assume no predictable association between stillbirth rate and low birthweight rate in countries in this region, but we did assume an association between stillbirth rate and low birthweight rate in countries outside this region.

We also investigated the following categorical predictors: type of data source (health facility data from sites with >90% institutional births, referred to here as health facility datapoints with probable minimal bias, health facility data with probable bias [ie, from sites with low institutional birth rates], DHS or other nationally representative survey, vital registration data and stillbirth registry data from countries with good vital registration, vital registration data and stillbirth registry data from countries without good vital registration, or other); stillbirth definition used (≥500 g birthweight; ≥1000 g birthweight or ≥28 weeks of gestation; other); source population (urban, rural, mixed, or unreported); and region (based on MDG regions: low mortality [developed], high mortality [sub-Saharan Africa and south Asia], and intermediate mortality [other regions]). Variables were retained in the model if there was evidence of predictive value after taking into account the other variables in the model ($p<0·10$). For the 129 countries contributing data to the input dataset, the best linear unbiased prediction of the country-specific random effect was obtained.

The following variables were retained for prediction purposes in the model: log(neonatal mortality rate) (cubic spline), log(low birthweight rate) (cubic spline), log(GNI PPP) (cubic spline), type of data source (categorical variable, six categories), definition of stillbirth used (categorical variable, three categories), and region (categorical variable, three categories). Webappendix p 44 provides the full model equation.

Stillbirth rate prediction

For 33 countries that met our inclusion criteria for data reliability, timeliness, and definition, we used the reported rates without adjustment. For the remaining 160 countries, we estimated the stillbirth rate as follows. The parameter estimates from the final model were used for country-level covariate data for 1995, 2000, 2005, and 2009 to predict the logarithm of the stillbirth rate for each of the 193 countries for these years, with vital registration as the gold standard for low-mortality countries and health facility data with likely minimal bias as the gold standard for high-mortality countries. For countries with data in the estimation dataset, the best linear unbiased prediction of the country-specific random effect was included in the prediction of the log(stillbirth rate). For countries with no data in the estimation dataset,

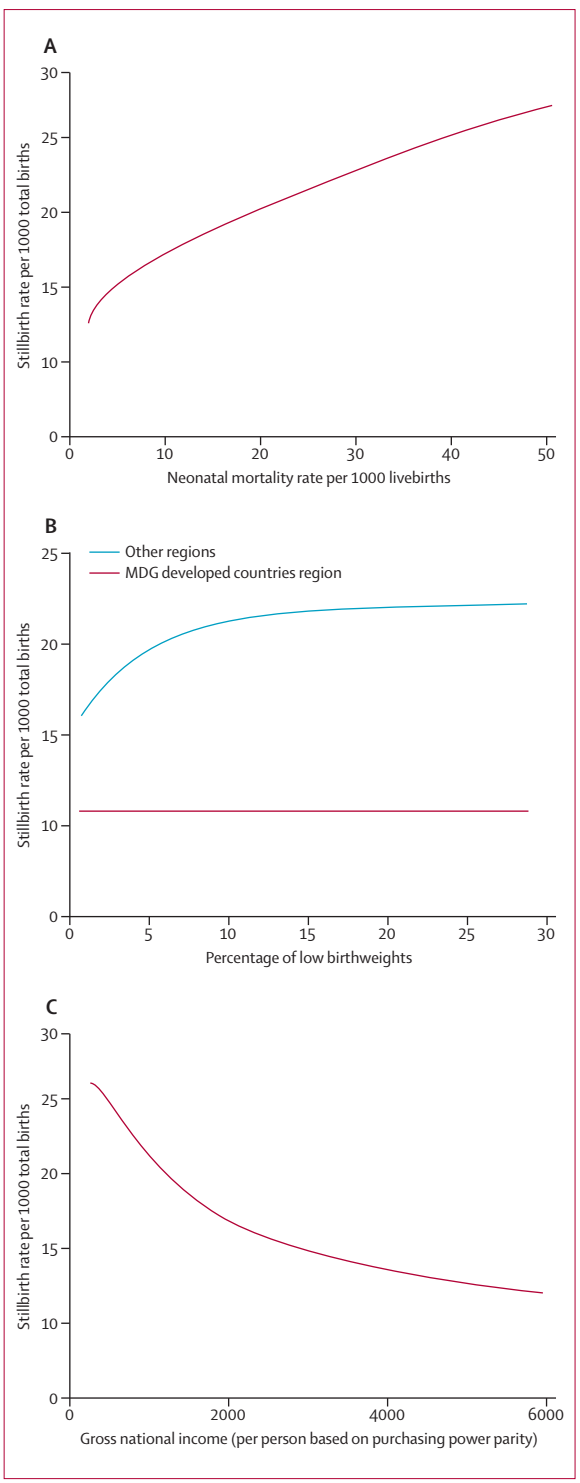

***Figure 3*: Association between stillbirth rate with restricted cubic splines and predictor variables**

(A) Against neonatal mortality rate per 1000 livebirths. (B) Against low birthweight rate per 1000 livebirths. (C) Against gross national income (purchasing power parity) per person. For high-income countries, the relation between stillbirth rate and low birthweight is assumed to be constant because the variation in stillbirth rate is so small that a meaningful association cannot be established. MDG=Millennium Development Goal.

	Risk ratio (95% CI)
Data source	
Health facility data with minimal bias*	1·00
Health facility data with bias	1·08 (0·92–1·26)
DHS or other retrospective survey	0·65 (0·55–0·76)
Good vital registration or national stillbirth registry*	0·70 (0·57–0·84)
Poor vital registration	0·62 (0·54–0·72)
Definition of stillbirth used	
>500 g birthweight	1·00
>1000 g birthweight*	0·68 (0·63–0·73)
Other definition	0·85 (0·78–0·92)
Region	
High-income country*	1·00
Other	1·01 (0·33–0·83)
South Asia and sub-Saharan Africa	0·71 (0·44–1·15)

DHS=demographic and health survey. *Indicates categories used for prediction purposes as the baseline.

Table 2: **Risk ratio estimates for categorical variables predictive of stillbirth rates**

the random effect was assumed to be zero. The predicted log(stillbirth rate) for each country was then combined with the estimated number of livebirths in that country to obtain the estimated number of stillbirths.

For our main analysis, we used the most recent neonatal mortality rate time series from WHO[15] (February, 2011), but undertook a sensitivity analysis to study whether the neonatal mortality rate estimates produced by the Institute for Health Metrics and Evaluation[18] materially changed the estimated stillbirth results.

Uncertainty estimation

Estimates of uncertainty were generated by drawing 1000 bootstrap samples from the estimation dataset and repeating the estimation steps for each sample.[19] We used the stillbirth rate parameter estimates for each sample, including the estimate of the country-specific random effect, to generate a new set of predictions (including predictions for both urban and rural populations in countries with moderate or high neonatal mortality). For countries not included in the bootstrap sample, and therefore without an estimate of the country-specific random effect, we randomly generated a country-specific effect by use of the estimated between-country SD derived from the bootstrap sample. We thus assumed that the random effects for these countries had the same distribution as the random effects for the countries in the bootstrap sample. To obtain worldwide and regional level estimates of uncertainty, we summed the data at worldwide or regional level for each bootstrap prediction run and used the 2·5th and 97·5th centiles of the resulting distributions around the estimated number of stillbirths by country. Because about 50% of countries had a country-specific random effect generated at random for each bootstrap prediction, some of which were positive and others negative, the relative uncertainty at the regional and worldwide level tends to be less than that at the individual country level.

For countries with good vital registration and with data on reported rates using the correct definition, we assumed that the standard error of the reported number of stillbirths was the square root of the reported number (ie, to follow a Poisson distribution).

Role of the funding source

The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. SC and JEL had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

The final dataset used (figure 2) comprised 1149 datapoints for stillbirth rate, after exclusion of 39 datapoints as implausible outliers (37 with a stillbirth rate to neonatal mortality rate ratio of <0·25, and two with a stillbirth rate to neonatal mortality rate ratio of >4·0). 527 datapoints (45·9%), with a median reference year of 2002 were from countries in regions of low neonatal mortality; 467 datapoints (40·6%; 2002) were from countries in regions of moderate neonatal mortality; and 155 datapoints (13·5%; 2002), were from countries in regions of high neonatal mortality (table 1).

Most datapoints were from vital registration systems or national stillbirth registries, including Euro-Peristat and the Council of Europe (84·2%). 6·0% were from nationally representative surveys, mainly DHS; 1·4% were derived from hospital-based studies in settings with high institutional birth rates (assumed to provide unbiased estimates of the population stillbirth rate), and 4·3% were from hospital-based studies in settings with low institutional birth rates (likely to overestimate stillbirth rates). The remaining 4·1% was predominantly, but not exclusively, from population-based, subnational studies (table 1; webappendix pp 1–43).

The high-mortality regions had fewer high-quality datapoints than did the low-mortality regions. For example, there were only three facility-based studies with likely minimal bias and five vital registration datapoints with good coverage (from Mauritius) available from countries in the high-mortality regions (sub-Saharan Africa and south Asia).

Figure 3 shows the modelled association between stillbirth rate and neonatal mortality rate ($p<0·0001$), low birthweight rate ($p=0·0004$), and GNI PPP ($p<0·0001$). The stillbirth rate is predicted to increase steadily with increasing neonatal mortality rate, to increase rapidly in low-income and middle-income countries with increasing low birthweight rate up to about 10% and more slowly thereafter, and to decrease steadily with increasing GNI PPP.

Categorical variables for which there was evidence of predictive value and which were therefore retained in the model were: data source (p<0·0001), stillbirth definition (p<0·0001), and region (p=0·001). Table 2 shows the estimated risk ratios associated with these categorical variables. Compared with data from health facilities thought to have little bias (ie, >90% facility births), facility-based data subject to bias tended to overestimate stillbirth rate as expected (by about 10%), whereas other data sources tended to produce lower estimates of the stillbirth rate. In particular, DHS and other nationally representative datasets based on retrospective data collection produced estimated stillbirth rates 35% below those from facility-based studies with minimal bias.

Regression diagnostic plots (figure 4) suggest that the model fits the data well (overall R^2=0·81). Both the estimates of the country-specific random effects (SD 0·25, figure 4B) and the residuals for the individual datapoints included in the estimation step (SD 0·22, figure 4C) seem to be approximately normally distributed.

Table 3 summarises the distributions of births and stillbirths at the regional and worldwide level (for individual country findings for 2008 and 2009 see webappendix pp 45–55). The total predicted number of stillbirths in 2009 was 2·64 million (uncertainty range 2·14 million to 3·82 million), corresponding to a worldwide average stillbirth rate of 18·9 per 1000 births (uncertainty range 15·2–27·3 stillbirths per 1000 births). The estimated rate in 1995 was 22·1 per 1000 births (worldwide total 3·03 million, uncertainty range 2·37 million to 4·19 million stillbirths). These estimates suggest a 14·5% decline in the worldwide stillbirth rate over that period. However, there is major variation in the estimated declines by region. East Asia, dominated by China, is estimated to have had a 47·5% decline in the stillbirth rate between 1995 and 2009. The smallest percentage declines (<10%) were in Oceania and sub-Saharan Africa. China, Bangladesh, and India, were estimated to have had almost 400 000 fewer stillbirths in total in 2009 than in 1995.

The regions with the highest stillbirth rates in 2009 were in south Asia and sub-Saharan Africa (table 4, webappendix pp 54–55). At a national level, the lowest stillbirth rates (all reported) were in Finland and Singapore (both 2·0 per 1000 births) and in Denmark and Norway (both 2·2 per 1000 births). The five countries with the highest rates (all estimated) were Pakistan (47 per 1000 births), Nigeria (42 per 1000 births), Bangladesh (36 per 1000 births), Djibouti (34 per 1000 births), and Senegal (34 per 1000 births). Ten countries (India, Pakistan, Nigeria, China, Bangladesh, Democratic Republic of the Congo, Ethiopia, Indonesia, Tanzania, and Afghanistan), which contribute 54% of total worldwide births, accounted for 67% of all stillbirths (1·76 million).

There was no evidence of a systematic difference between the modelled estimated stillbirth rate for 2009 and the nationally reported rate in the 33 countries where nationally reported rates were available for stillbirths of more than 1000 g birthweight or at least 28 weeks' gestation between 2007 and 2009, and of acceptable quality of data for maternal mortality ratio[14] (paired *t* test p=0·87). The median difference between estimated and reported rates was 2·9% (IQR –10·0 to 11·5; table 4).

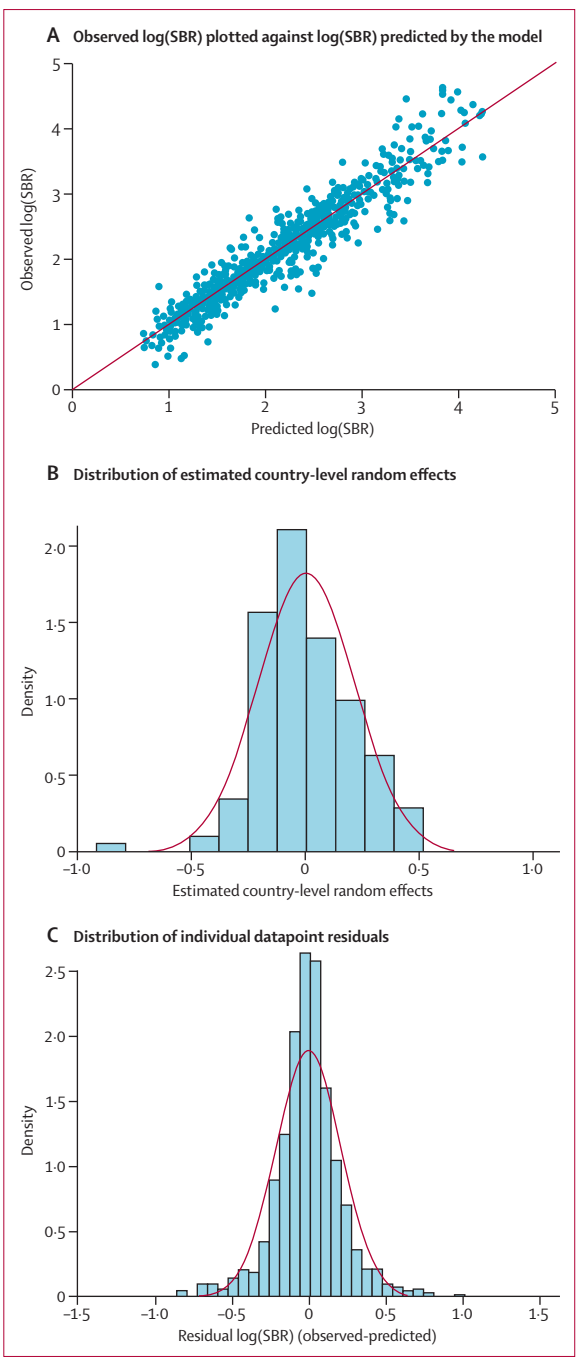

Figure 4: **Diagnostic plots for the stillbirth prediction regression model**
(A) Observed log(SBR) plotted against log(SBR) predicted by the model. (B) Distribution of estimated country-level random effects. (C) Distribution of individual datapoint residuals. SBR=stillbirth rate.

	1995			2009			Reduction in stillbirth rate from 1995 to 2009
	Number of births (millions)	Number of stillbirths (1000s; uncertainty range)	Stillbirth rate per 1000 total births (relative uncertainty range [%])	Number of births (millions)	Number of stillbirths (1000s; uncertainty range)	Stillbirth rate per 1000 total births (relative uncertainty range [%])	
High-income region	11·7	45·8 (45·1 to 48·7)	3·9 (–1·6 to 6·3)	11·7	36·4 (35·7 to 38·0)	3·1 (–2·0 to 4·5)	20·3%
Eurasia (CIS in Asia)	1·7	17·9 (15·8 to 24·9)	10·5 (–11·8 to 39·0)	1·6	13·8 (12·3 to 19·0)	8·8 (–11·0 to 37·5)	16·0%
Eurasia (CIS in Europe)	2·1	22·8 (21·0 to 31·6)	10·9 (–8·1 to 38·2)	2·2	19·7 (17·5 to 24·7)	9·0 (–11·1 to 25·3)	17·6%
East Asia	22·4	414·3 (280·0 to 636·7)	18·5 (–32·4 to 53·7)	19·4	188·5 (131·1 to 294·4)	9·7 (–30·4 to 56·2)	47·5%
Latin America and the Caribbean	11·7	141·9 (119·8 to 178·1)	12·1 (–15·6 to 25·5)	11·2	97·1 (82·6 to 122·7)	8·7 (–14·9 to 26·4)	28·0%
North Africa	3·5	61·8 (46·0 to 93·5)	17·7 (–25·5 to 51·4)	3·8	51·3 (40·2 to 77·6)	13·6 (–21·8 to 51·1)	22·92%
Oceania	0·2	3·7 (2·7 to 7·3)	15·8 (–27·1 to 96·9)	0·3	3·9 (2·8 to 7·6)	14·5 (–28·6 to 96·1)	8·0%
South Asia	41·3	1248·4 (920·7 to 1912·2)	30·2 (–26·2 to 53·2)	40·5	1080·3 (855·8 to 1651·2)	26·7 (–20·8 to 52·9)	11·7%
Southeast Asia	11·8	198·5 (154·3 to 278·6)	16·8 (–22·3 to 40·3)	11·2	156·1 (123·9 to 219·6)	13·9 (–20·6 to 40·7)	17·1%
Sub-Saharan Africa	26·0	807·6 (593·2 to 1169·6)	31·0 (–26·5 to 44·8)	33·0	934·6 (706·9 to 1406·8)	28·3 (–24·4 to 50·5)	8·7%
West Asia	4·6	68·5 (50·7 to 99·8)	14·9 (–26·0 to 45·8)	5·0	60·2 (47·3 to 88·3)	12·0 (–21·4 to 46·7)	19·2%
Total (all countries)	137·0	3031·3 (2369·3 to 4189·6)	22·1 (–21·8 to 38·2)	139·7	2642·0 (2135·0 to 3818·9)	18·9 (–19·2 to 44·5)	14·5%

Numbers are rounded to one decimal place; rates were calculated with raw, unrounded data. CIS=Commonwealth of Independent States.

Table 3: **Predicted stillbirth rates and totals for 1995 and 2009, by Millennium Development Goal region**

These stillbirth rate estimates are affected by the input time series for neonatal mortality. We identified no evidence of a systematic difference between the estimated stillbirth rates by use of the neonatal mortality rate time series from the Institute for Health Metrics and Evaluation[18] or from WHO at either a regional level (paired *t* test p=0·45) or at country level (paired *t* test p=0·74; webappendix p 56). The estimated global total of stillbirths in 2009 was 2·68 million by use of the neonatal mortality rate time series from the Institute for Health Metrics and Evaluation, compared with 2·64 million by use of the corresponding estimates from WHO. In five countries (United Arab Emirates, Laos, Central African Republic, Côte d'Ivoire, and Moldova), the stillbirth rate estimates differed by more than 10%.

Our estimate of the worldwide number of stillbirths in 2000 was 2·8 million, lower than the previous estimates of 3·2 million[2] and 3·3 million,[1] but similar to the estimates generated by both of these reports before their post-modelling upward adjustments.

Discussion

We estimated yearly national stillbirth rates and numbers from 1995 to 2009. The estimated number of global stillbirths was 2·64 million in 2009 compared with 3·03 million in 1995. In view of the expanded and updated input data, especially with a systematic country consultation and improved modelling, including avoidance of post-modelling adjustments in countries with high stillbirth mortality rates, these results provide more accurate and updated data than do the two previous studies to estimate the worldwide number of stillbirths in 2000 (panel). This study is the first analysis for stillbirths over time. The estimated stillbirth rate decreased by about 1·1% per year from 1995 to 2009. This estimated trend is affected by trends in the model covariates: neonatal mortality rate, low birthweight rate, and GNI PPP. This estimated rate of reduction is lower than that for mortality in children younger than 5 years (2·3% per year),[18] and is similar to one of two independent estimates of the rate of reduction in maternal mortality between 1990 and 2008 (1·3%[20]) and is lower than the other estimate (2·3%[14]). At a regional level, our model shows little reduction in the stillbirth rate in sub-Saharan Africa, despite increasing progress in reducing deaths in children younger than 5 years.[21] This finding is consistent with recent analysis suggesting that there has been little reduction in maternal mortality in sub-Saharan Africa,[22] which might be associated with HIV infection as well as poor progress in increasing coverage of skilled birth attendance and emergency obstetric care and extremely low coverage of rural caesarean section rates.[23,24] The fact that neonatal mortality rate is a strong predictor of stillbirth rate in our model is understandable because many of the programmatic factors affecting these two outcomes are closely linked.[25]

There was no evidence of a systematic difference between the modelled estimated stillbirth rate and the nationally reported rate in the 33 countries with

	Total births	Estimated stillbirth rate per 1000 total births	Estimated number of stillbirths	Reported stillbirth rate per 1000 total births	Number of stillbirths using reported rates	Relative difference between estimated and reported rates (%)	Absolute difference in number of stillbirths
Chile	254 390	4·9	1250	8·9	2260	−80·1	−1010
Slovakia	55 730	2·7	150	3·7	210	−34·6	−60
Hungary	99 190	3·1	310	3·8	370	−20·9	−60
Lithuania	31 700	3·6	110	4·1	130	−14·9	−20
Estonia	16 380	3·3	50	3·7	60	−11·4	−10
Canada	359 280	3·0	1080	3·3	1180	−11·2	−100
Spain	500 310	2·9	1450	3·2	1620	−11·2	−170
Bulgaria	73 390	5·9	430	6·6	480	−11·1	−50
Serbia	114 160	4·5	510	5·0	570	−10·5	−60
New Zealand	58 790	3·2	190	3·5	210	−9·8	−20
Luxembourg	5520	2·8	20	3·0	20	−7·7	0
Czech Republic	111 330	2·5	280	2·7	300	−6·8	−20
UK	751 370	3·4	2550	3·5	2630	−4·2	−80
Austria	75 970	3·6	270	3·7	280	−3·4	−10
Poland	416 440	3·3	1370	3·4	1420	−2·8	−50
Sweden	108 340	2·7	290	2·7	300	−0·7	−10
Finland	59 540	2·1	130	2·0	120	2·9	10
Israel	157 310	3·5	550	3·4	530	3·8	20
Portugal	103 690	3·0	310	2·9	300	4·5	10
Netherlands	183 490	3·5	640	3·3	610	5·7	30
Romania	212 800	4·5	960	4·2	890	7·6	70
Iceland	4710	2·6	10	2·4	10	8·7	0
Mauritius	18 260	9·8	180	8·9	160	9·1	20
Norway	58 310	2·4	140	2·2	130	9·9	10
Argentina	694 740	5·6	3890	5·0	3510	10·9	380
Malta	3710	3·6	10	3·1	10	12·7	0
Italy	544 120	3·1	1690	2·7	1470	13·1	220
Denmark	61 800	2·6	160	2·2	140	16·3	20
Australia	270 360	3·5	950	2·9	780	16·8	170
Croatia	42 610	3·6	150	3·0	130	17·1	20
Mexico	2 636 110	5·5	14 500	4·5	11 940	18·1	2560
Singapore	37 260	2·5	90	2·0	70	18·5	20
Colombia	715 450	7·8	5580	5·5	3950	29·5	1630
Median difference	..	..	..	..	..	2·9	..
Total difference in number of stillbirths	..	..	..	..	..	..	3460

Numbers are rounded; rates were calculated with raw, unrounded data. Definition of stillbirth used was the international definition (≥1000 g birthweight or ≥28 completed weeks of gestation).

Table 4: **Comparison of estimated stillbirth rates for 18 countries with reported rates by use of the same definition between 2007 and 2009**

acceptable quality for maternal mortality ratio reporting (table 4). However, Chile is noted to be an outlier, with an estimated stillbirth rate of 4·9 per 1000 births for 2009 and reported rates from 2007–09 of 8·7–8·9 per 1000 births. This estimate is, however, consistent with the rates of 4·1–4·9 reported between 1997 and 2002 with the same definition. Vital registration data, when collected and reported by gestational age or birthweight alone, underestimated the stillbirth rate in Norwegian and Australian historical data for stillbirths at 22 weeks and older or 500 g birthweight and more by 19–30%, although in Norway once the stillbirth rate was less than five per 1000 total births, the under-reporting was reduced to about 10%.[26] Thus, vital registration data cannot be thought of as an unalloyed gold standard. Comparison of the estimated trends with reported trends by country suggests that the current model's accuracy of predicting trends is close to that of the actual reported trends.[27,28] Furthermore, the variation in the estimated declines by region needs recognition. For example, the reduction

Panel: Research in context

Systematic review

Stillbirths are not included in worldwide health targets and, until now, data for stillbirth rate were not routinely collected or collated by UN agencies. Two studies to estimate country-level stillbirth rates for 2000 used different methods and did not estimate trends.

Stillbirth definitions vary between countries, especially in high-income countries, with poor compliance with definitions for international reporting of late fetal death (≥1000 g birthweight or ≥28 completed weeks of gestation).

We assessed data from several sources and the following were included based on preset inclusion criteria: (1) vital registration or national surveillance systems from 79 countries, (2) nationally representative surveys from 39 countries, and (3) 113 studies from 56 countries identified through systematic reviews of published reports.

Interpretation

This study advances the modelling methods for national stillbirth rates. We used the new model for 129 countries without good vital registration trend data, providing estimates (for 2009) and enabling trend assessment from 1995 to 2009.

The estimated number of worldwide stillbirths in the third trimester for 2009 was 2·64 million (uncertainty range 2·14 million to 3·82 million). This number is similar to the number of early neonatal deaths in 2009 and about eight times the number of maternal deaths, and is closely linked to both these outcomes for causation and solutions.

Worldwide, third-trimester stillbirths in 1995 were estimated at 3·03 million (uncertainty range 2·37 million to 4·19 million), suggesting yearly rate of reduction of 1·1% in the stillbirth rate between 1995 and 2009. This reduction is probably associated with investments in maternal health care but is not being systematically tracked. Progress could be better assessed and accelerated with improved data and use of data.

Increasingly complex modelling even with improved transparency and country consultation as we use here, is an advance but is not the long-term solution. Leadership is needed to improve the quantity, quality, and frequency of stillbirth rate data, to collect data, and to provide yearly estimates.

seen in east Asia, dominated by China, is indicative of major changes in the values of model predictor variables for China: the neonatal mortality rate (down from 22·6 neonatal deaths per 1000 livebirths in 1995, to 11·4 neonatal deaths per 1000 livebirths in 2009), the low birthweight rate (down from 9·0% to 2·7%), and GNI PPP (up from about US$1500 to about $6000).

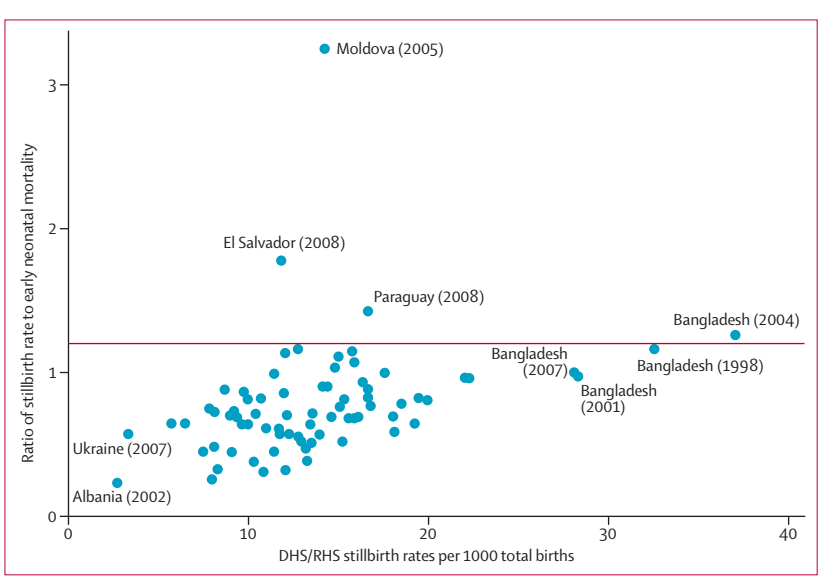

Figure 5: **Retrospective survey data for 41 countries from 76 DHS or RHS, showing ratios of stillbirth to early neonatal mortality rates according to stillbirth rate**

The expected ratio is at least 1·2 (indicated by the central horizontal line). There were four surveys for Bangladesh. DHS=demographic and health survey. RHS=reproductive health survey.

The ranking of countries by stillbirth rates is affected by the number of data sources available for that country. The model predicts high stillbirth rates for some low-income countries that provided several datapoints; for example, the datapoints for Nigeria and Pakistan enabled the calculation of a country-specific random effect, which increased the modelled estimates for these countries. Somalia and Afghanistan have none or one country-specific datapoint, resulting in zero or small country-specific random effects; therefore, these countries have lower stillbirth rates than those predicted for Pakistan and Nigeria. In view of the poor quality and quantity of stillbirth data available, and absence of systematic yearly collation of national data, all studies must be viewed as attempts to make the best use of deficient data. For some other mortality outcomes, worldwide estimates are based on stronger input data. For example, the dataset used by the UN to estimate child mortality rates includes only national, population-based data for child mortality for that country. In this study, no data were available at all for 64 of 193 countries, whereas for 17 countries (Afghanistan, Côte d'Ivoire, Democratic Republic of the Congo, Iran, Mauritania, Nigeria, Oman, Pakistan, Papua New Guinea, South Africa, Sudan, Thailand, Trinidad and Tobago, United Arab Emirates, Venezuela, Vietnam, Yemen), the data that were available are unlikely to be nationally representative. Given the input data, the only option is to use a statistical model to try to correct for this bias and to extrapolate to countries for which no data are available, based on a small number of predictor variables.

National surveys, particularly the DHS, are our largest source of national population-based child mortality data. If data for stillbirth rates are to be improved, then it is essential to improve the capture of fetal deaths through DHS and to consider refinements to UNICEF's multiple indicator cluster surveys, such as use of a livebirth history and single stillbirth question or use of a pregnancy history module. DHS tends to underestimate the stillbirth rates in most countries.[4,29] Figure 5 shows the ratio of stillbirth rates to early neonatal mortality rates for 76 DHS surveys from 41 countries based on all data available.[30] The median ratio across DHS estimates is 0·71, with 12 (16%) ratios of the sample below 0·50. 72 (95%) of these ratios are less than the ratio of 1·2 suggested by historical data from settings with early neonatal mortality rates of 20 or more per 1000 births.[1] By contrast, the observation from Moldova stands out as an outlier with a ratio of 3·2. In the 2000 worldwide stillbirth exercise, DHS datapoints were 30% lower than were other population-based stillbirth rate estimates after controlling for other variables in the model.[2] In our stillbirth rate estimation model, DHS estimates were 36% lower than our gold standard of health facility data with little bias.

We have a choice about future approaches to documentation of national stillbirth rates. We can continue to accept marginal improvements in the modelling step or we can resolve to improve the quality and quantity of stillbirth data, especially for low-income countries.[31] Achievement of this goal will require inclusion of stillbirths in vital registration and increasing support for the infrastructure and training needed to improve vital registration and national stillbirth registries. Worldwide collation of these data will also be needed, as proposed in the Global Alliance to Prevent Prematurity and Stillbirth global report[4] and supported by a wider consensus group in *The Lancet*'s Stillbirths Series.[32,33]

In 2020, will the global health community be preparing yet another revision of global stillbirth estimates mainly based on modelling? We hope not. Improvements in vital registration and household surveys, with worldwide agencies taking up responsibility for stillbirths, could make modelling exercises extinct and show that stillbirths really count.[32] Women and families certainly believe that they do.[34,35]

Contributors

SC led the final statistical modelling and helped to write the paper. HB undertook the final modelling and time series and helped to write the paper. CS provided oversight for the literature review and data compilation, did initial analysis, and helped to write the paper. LSt coordinated and contributed to the literature review. SA provided programming assistance for the analyses of the DHS data and statistical guidance for the modelling exercise. AAC was responsible for the analysis of the DHS data and contributed to the literature review. ÖT, ZPB, and SG contributed to the literature review and assisted in the editing of the paper. DC and LSa contributed to the literature review, identification and assessment of data, and coordinated the WHO country consultation. JEL planned the overall process, including collation of the input data, modelling, time series, consultations, and preparation of the paper.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

We thank Ann-Beth Moller, Mie Inoue, Mikkel Z Oestergaard, and Colin Mathers for reviewing the data inputs and support during the WHO country consultation and the many national statistical offices and others who provided their national stillbirth data. We thank Vicky Flenady, along with colleagues in the International Stillbirth Alliance who provided stillbirth rate data for their countries and reanalysed data according to the definition for international comparison; Carla Abou Mrad, Yelena Hope, and Konstantinos Kordellos at WHO for their assistance with translation; Ann Lovold for assistance with electronic searches during the initial literature review; and colleagues in *The Lancet*'s Stillbirth Series committee for useful insights. The authors alone are responsible for the views expressed in this publication and they do not necessarily represent the decisions, policy, or views of WHO or of any other organisation. Funding sources were the Bill & Melinda Gates Foundation through the Global Alliance to Prevent Prematurity and Stillbirth, Saving Newborn Lives/Save the Children, and the International Stillbirth Alliance. The Department of Reproductive Health and Research, WHO, through the UN Development Programme, UN Population Fund, WHO, and World Bank Special Programme of Research, Development and Research Training in Human Reproduction.

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